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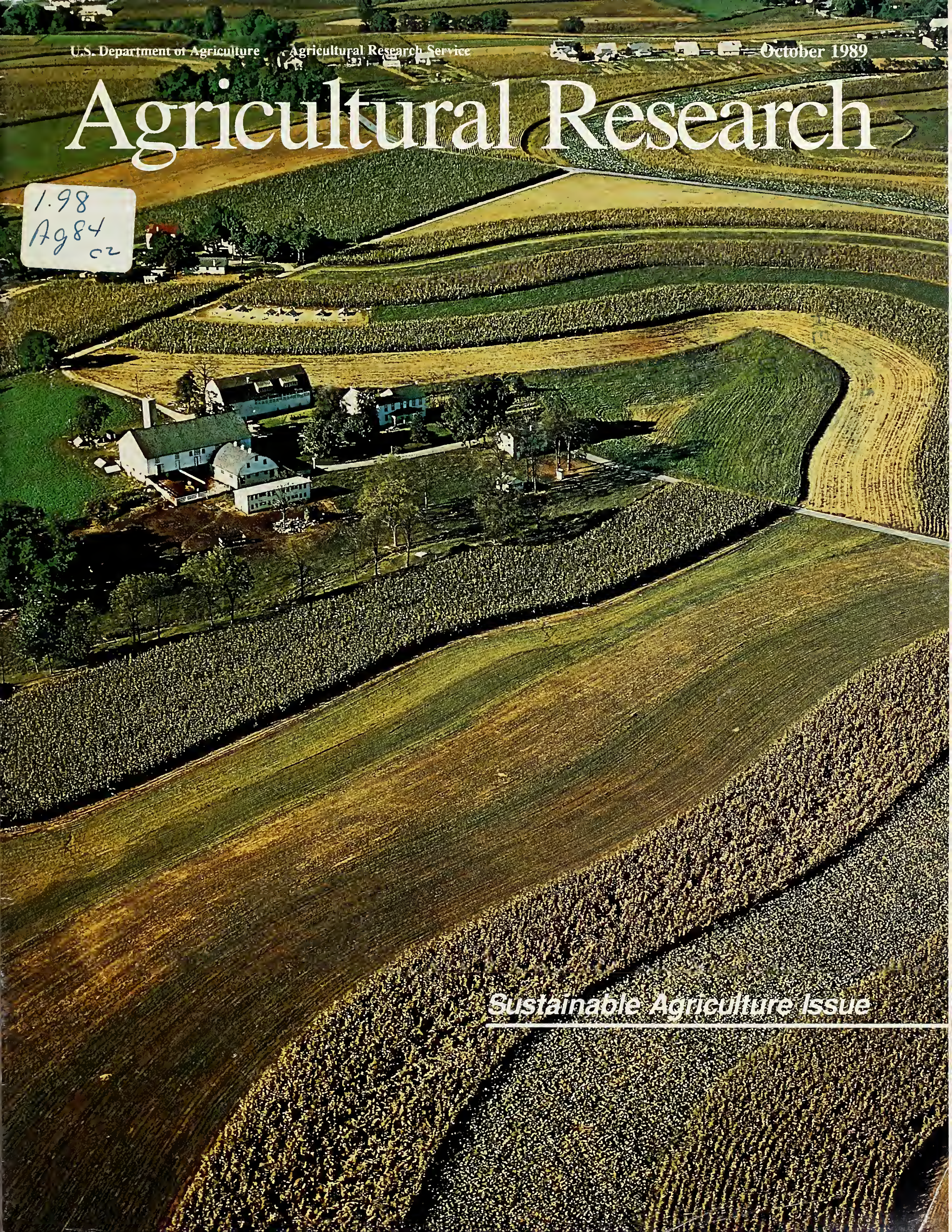

Sustainable Agriculture Issue

FORUM

Sustaining Agriculture

Some call it sustainable agriculture; others use terms such as alternative, biological, low-input or organic farming.

Whatever the words, no one can ignore that public interest in this topic is growing dramatically. That debate took on a new dimension last month with the release by the National Research Council of its report on "Alternative Agriculture."

I won't attempt to summarize the Council's report in this brief space, but some points are worth noting.

For example, it notes that alternative farming practices are far more than conventional agriculture with lowered inputs of fertilizer and pesticides. Instead, alternative farming encompasses an array of options that "emphasize management and take advantage of biological relationships that occur naturally on the farm."

The report also notes that alternative agriculture requires more knowledge and better management skills than does conventional farming, and concludes that "with appropriate changes in farm policy and expanded and redirected research and extension efforts, the rate of progress in developing and adopting alternative systems could be markedly increased."

Likewise, the report recommends a new, $40 million competitive grants program administered by USDA to study alternative methods, and urges that future research emphasize "farming systems" and a multidisciplinary approach to solving agricultural problems.

From my perspective, this study merits sincere and objective consideration.

America's farmers face many challenges.

On the one hand, they need to be highly efficient and internationally competitive in order to stay economically viable.

At the same time, they need help in maintaining farming operations that are environmentally sensitive and whose products are viewed as safe by consumers. Both those goals are attainable.

Here in the Agricultural Research Service, we are putting some $100 million annually into that effort. By major research categories, that includes:

- **Biological pest control and integrated pest management (IPM) of insects, soil nematodes, crop toxins, weeds, and internal animal parasites and diseases: $42,420,000.**

  Success abounds in these programs since the first biocontrol for a citrus scale was used 100 years ago. Cost savings to growers for control of just 4 insect pests is estimated at $100 million annually.

- **Improving crop varieties for resistance to acid soils, air pollution, insects, soil nematodes, diseases, drought, and other stresses: $21,480,000.**

  Recent studies include a search for crop varieties that can maintain or increase yields and quality despite threats such as higher levels of ultraviolet rays caused by a thinning of the earth's ozone layer.

- **Water and soil management to conserve water, improve its quality, and sustain production: $9,340,000.**

  This covers a broad range of improved farming practices, from conservation tillage to using deep-rooted crops in crop rotation programs so as to capture soil moisture and nutrients that have filtered down below normal root depths.

- **Management systems which are economical, environmentally sound, and sustainable: $6,380,000.**

  Computer programs "lend a hand" to farm managers. The Gossym/Comax system now being used in Mississippi and other cotton-growing states is just such a package. Its advice helps farmers grow better quality and higher yielding cotton with the lowest possible inputs.

- **Erosion control and prediction: $5,490,000.**

  Computer programs such as WEPP (Water Erosion Prediction Project), EPIC (Erosion Productivity Impact Calculator), and SWRRB (Simulator for Water Resources in Rural Basins) are forerunners in a new era of computer-aided wind and water erosion prevention through improved forecasting.

- **Nutrient management to reduce fertilizer use, avoid water pollution, and maintain yields: $4,550,000.**

  Rising concern about groundwater contamination from agricultural chemicals has added impetus to this research. ARS scientists are studying ways to integrate many production practices into soil and crop management systems that are efficient in using nitrogen from all sources without degrading the environment.

- **Forage production and animal production: $3,050,000.**

  Forage crops that grow vigorously earlier in the spring, withstand the heat of summer, and continue their growth later into the fall are being developed to extend the grazing season and reduce the length of time livestock owners must feed their animals more expensive feeds. Animals are also being bred to produce more pounds of meat or milk per unit of feed, whatever its source.

- **Beneficial organisms: $800,000.**

  Genetic engineering and scientific selection are improving such organisms as rhizobia which fix nitrogen for soybeans and other legumes.

This issue of Agricultural Research highlights in more detail a sampling of these research efforts geared to sustaining American agriculture.

R.D. Plowman
Administrator

Agricultural Research

Diversified small farms
in Pennsylvania.
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DEPARTMENTS

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Editor: Lloyd E. McLaughlin
Associate Editor: Regina A. Wiggen
Photography: Anita Daniels, John Kucharski

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Clayton Yeutter, Secretary
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Alternative vs. Conventional Farming

Iowa farmers Dick Thompson and David Snyder have a neighborly disagreement: Are alternative farming methods such as organic farming better for soil and groundwater than conventional farming?

Both farmers keep an open mind on the issue, though—so open, they are allowing a team of scientists from various federal and state agencies to take a close look at their farms.

The Agricultural Research Service's National Soil Tilth Laboratory in Ames, Iowa, led the farm comparison project.

Scientists at the lab chose the project to get a realistic on-farm comparison of how different farming practices affect soils, groundwater, crops, and farmers' wallets.

Jerry L. Hatfield, lab director, says, "This is one of the first studies to combine basic scientific studies with an economic analysis."

Last spring the scientists selected for the study two adjacent 40-acre fields about 5 miles northeast of Boone, Iowa, one on Thompson's land and one on land that Snyder farms. They've divided each field into a grid with 64 squares. At each grid intersection they've inserted a probe and removed a soil profile core from 10 to 15 feet deep.

"That makes my field the most studied in the country," jokes Thompson, who's grown quite accustomed to the sight of researchers crawling around his 300-acre farm.

Thompson has used no pesticides or commercial nitrogen fertilizer on his farm since 1967, except for a few experimental plots. He had previously designed the farm to be a private research farm.

Not so for Snyder. Along with his son, he farms 1,400 acres with an eye to producing income, not research data. Although Snyder's farm is considered a conventional operation, he uses many conservation techniques

LOWELL GEORGIA

Above: Farmer Dick Thompson, a proponent of ridge tillage, cultivates his study plot. He says it eliminates the need for fall and spring preplant tillage. (K-3239-1)

LOWELL GEORGIA

Right: A closeup of Buffalo ridge tiller that Thompson is operating. (K-3239-12)

that have been assimilated into conventional farming the past two decades. Many of his practices are similar to what Thompson is doing, techniques considered innovative and unconventional just a few years ago.

Snyder uses minimum tillage techniques, having abandoned the moldboard plow. He uses a narrow chisel blade for his fall tillage to disturb the soil as little as possible. He tests his soil for fertilizer requirements every 2 years; he uses from 20 to 75 pounds less fertilizer per acre than he did in the 1960's. He's reduced his herbicide use by more than half.

Snyder's neighbor, Thompson, doesn't fault him for using commercial fertilizers—judiciously. In fact, Thompson believes that an organic farmer who tills in the fall may do more harm to soil than a conventional farmer who uses commercial fertilizers but doesn't till in the fall. Thompson prefers to call himself a "sustainable agriculture" farmer,

meaning he farms with techniques that sustain his natural and financial resources. He says the switch to sustainable agriculture has proven profitable in his case.

If Thompson has a beef with other farmers it's over fall tillage. "It's the reason earthworm populations decline," Thompson asserts, having seen a drop in earthworm numbers after he tilled some fields in the fall. He believes bountiful earthworms are a sign of soil health.

But Thompson is keeping an open mind on worms, too. As is Hatfield, who believes the appearance and disappearance of earthworms is one of many questions the study might shed some light on.

"Farmers might see a decrease one year after fall tillage and assume that's the cause. Ed Berry and I will be looking at the effects of tillage on worms. Maybe the worms just stay out of sight after fall tillage because it dries out the surface soil. But probably the answer is more complicated than that." Edward C. Berry is an entomologist at the tilth lab.

When Berry took core samples from the two fields, he noticed more earthworms in Thompson's field, but the jury is still out on who has more worms and how they are distributed throughout the growing season.

LOWELL GEORGIA

The appearance and disappearance of earthworms in the soil is one of the many questions researchers will be looking at on the two study farms. (K-3237-5)

LOWELL GEORGIA

Digitized map showing soil-type boundaries near the Thompson and Snyder farms. (K-3235-2)

Snyder says the labor requirements of tilling only in the spring could make the debate over fall tillage academic for many farmers: "Thompson's system works for him, but he has two men to help him farm 300 acres, while I have just my son to help me farm 1,400 acres," he says. "We don't have the help to till 1,400 acres in one spring," Snyder says.

Ridge Tillage Helps Control Weeds

Thompson is a proponent of growing crops on ridges—rows of unplowed raised beds. He says, "They eliminate the need for fall tillage and spring pre-plant tillage."

Because there's no plowing to stir up weed seeds with ridge tillage, Thompson has no difficulty keeping his weeds down. He controls weeds without herbicides with two trips across his fields with a tractor-driven rotary hoe and two trips with a cultivator each year. And he helps crops outcompete weeds by rotating the crops, planting densely, and using taller crop varieties.

Each year, he has some fields planted to corn, some to soybeans, some to oats, and some to hay. He rotates the fields so the same crop isn't planted in a field for 3 years. This breaks disease and insect cycles, so he hasn't had to use insecticides or disease-fighting chemicals.

Thompson uses manure from his 50 beef cows and calves and 1,200 hogs to fertilize his fields. He supplements the manure with sewage sludge as fertilizer. He also gets green manure from hairy vetch, which produces its own nitrogen fertilizer.

He plants a mixture of hairy vetch and rye as fall cover crops. Both crowd out weeds. In fact, the rye actually emits a natural herbicide under the right conditions.

John W. Doran, an ARS soil scientist stationed at the University of Nebraska, has spent the past 4 years learning how Thompson's management practices influence the way soil microbes consume the carbon and nitrogen in crop residues.

"There's a fascinating balance out there in which microbes use mostly carbon for energy and often need some nitrogen as a food supplement. When they require nitrogen, they're competing with crops for it. But they also can release nitrogen by breaking down residue rich in nitrogen. Thompson plans his crops with this delicate balance in mind. He plants rye for its high carbon content and hairy vetch for its nitrogen."

Doran and Thompson would like to see if slight changes in tillage can help crops use nitrogen more efficiently. The key is synchronizing things so nitrogen is available only when plants need it, so there won't be any excess soluble nitrates that might leach to groundwater.

"Thompson is trying to make sure soil microbes release nitrogen and

LOWELL GEORGIA

Soil scientist Doug Karlen (left) and research associate Neal Eash study the profile of the needle board on the Thompson farm. When the board with solid wires projecting below it is placed over the tilled rows and then lowered, the top of the needle row measures the roughness of the soil surface. (K-3236-3)

LOWELL GEORGIA

Research associates Neal Eash and Aaron Steinwand examine a soil core sample on the Thompson farm. Samples will be analyzed to see how nitrates and other nutrients are distributed throughout the soil as well as the carbon accumulations from decaying organic matter. (K-3238-4)

other nutrients from organic residues when crops most need them. If manure or sludge is needed for additional nutrients, he wants to apply them at the right time, also.

Thompson times his soil nitrate-nitrogen test to a certain crop growth stage, before the demand for nitrogen is highest. For corn, that occurs when plants are "6 to 12 inches high, usually between June 1 and June 15," Thompson says. "I use a new nitrate-testing technique that is more accurate than the old test. I find out how much additional nitrogen fertilizer my plants want, if any.

"For the past 2 years, additional purchased nitrogen has not increased my corn yields," he says. "That tells me that the nitrogen from the manure and sludge and legume crops is all the corn needs."

Thompson does buy commercial potash to supplement his sludge, which has almost no potassium.

Thompson says that farmers should not adopt his whole system. "Like all farmers, I have my own unique conditions—especially since I've made my farm a research farm. I also have livestock and am able to haul sewage sludge from nearby Boone. I wouldn't advocate that everyone try to replicate my system. I'd just like farmers to borrow bits and pieces and go only as far as they want to toward a system that's more sustainable," he says.

He agrees with Snyder that everyone can't raise enough livestock to have an adequate manure source. "If we all did that, the price of cattle would drop and drive us all out of the livestock business again," Snyder says. "But without livestock, I have no use for a hay crop to rotate with my corn and soybeans."

Thompson says he has a demonstration plot devoted to solving this problem for cash grain farmers like Snyder. "We have permanent ridges and plant four crops in a 7-year rotation: corn-bean-oats-green manure. We also have legume cover crops sandwiched in for erosion control and additional nitrogen."

The green manure substitute for animal manure, providing all the nitrogen needed. "We do add a limited amount of phosphorus and potassium, applying it only in a narrow band near the crop row."

Hatfield and Berry will study whether the different tillage methods used by Thompson and Snyder affect water evaporation and organisms in the soil differently.

"We want to see if ridge till could slow down evaporation because it leaves so much crop residue on the surface, especially between ridges," Hatfield says. "If so, then it could

mean more rainfall retained for plant use in one field than in a neighboring one that presumably gets the same amount of rainfall."

Hatfield will use a portable weather station to monitor the local weather for the two fields. He will also look at the microclimate, the weather conditions just above the soil, where the plant is growing.

He will measure such things as air temperature near cornstalks and evaporation rates for soil water. He will also measure soil moisture and temperature.

ARS scientists will also look at the soil profile for carbon accumulations from decaying organic matter.

Douglas L. Karlen, a soil scientist at the soil tilth lab, will check the soil samples taken from each field to see how nitrates, other nutrients and pesticides are distributed throughout the soil profile.

By inserting water pressure measuring tubes in the holes left when the sample soil cores were removed, scientists will check soil water movement that could carry chemicals past the root zone to groundwater.

The U.S. Geological Survey, which has federal responsibilities for monitoring deep below crop roots, will serve as a consultant for groundwater sampling.

Robert Grossman, a soil scientist with USDA's Soil Conservation Service, is working with Karlen and other researchers to study soil tilth at the surface. Tilth below the surface layer is being handled by Michael L. Thompson, an agronomist from Iowa State University.

When harvest time comes, Thomas S. Colvin, an agricultural engineer at the tilth lab, will come in with an automated combine that samples yields at each grid point. Yield variations will be compared with soil types and tillage method in each field. Next year, the lab's scientists plan to expand the study to two 80-acre parcels. And similar projects might begin in other states, Hatfield says.—By **Don Comis,** ARS.

LOWELL GEORGIA

Plant physiologist Jerry Hatfield sets up a weather station to study the Thompson and Snyder farm plots. The station records wind currents along with surface and soil subsurface temperatures at various depths. (K-3241-9)

Jerry L. Hatfield, Douglas L. Karlen, Edward C. Berry, and Thomas S. Colvin are at the USDA-ARS National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011 (515) 294-5723.

John W. Doran is in USDA-ARS Soil and Water Conservation Research, 119 Klein Hall, University of Nebraska, Lincoln, NE 68583 (402) 472-1514. ◆

LOWELL GEORGIA

Thermocouple sensors, linked to the weather station, measure soil temperature near young corn plants. (K-3241-3)

The Eyes of Texas Track The Boll Weevil

Cotton growers may reduce their pesticide use by 50 percent or more by destroying their plants once the harvest is over.

A 7-year U.S. Department of Agriculture study on boll weevils in the Lower Rio Grande Valley of Texas found that leftover cotton stalks provide great food and protection for the weevil during fall and winter months.

"If ignored, these conditions usually produce a large population of overwintered weevils to infest the spring cotton crop," says Kenneth R. Summy, an entomologist with USDA's Agricultural Research Service.

The result is heavy pesticide use to control the insects. In 1980, growers applied pesticides 15 to 18 times before harvest, he says. After a year of moderate stalk destruction in 1984, pesticides were applied an average of only four to five times. From 1985 to 1987, pesticide use increased to as many as 11 applications. Not all growers destroyed stalks in that period.

TIM McCABE

Entomologist Ken Summy examines wintering cotton for signs of boll weevil populations. (K-2516-14)

In cooperation with James R. Cate of Texas A&M University and officials of the Cotton and Grain Producers Association of the Lower Rio Grande Valley, scientists set out to investigate the impact of early stalk destruction on overwintering weevils.

They found that eliminating the cotton plants drastically reduced reproduction, hibernation, and development of weevils in dried bolls. In addition, the late summer sun kills many of the remaining weevils exposed to hot soil surface temperatures.

TIM McCABE

Through aerial infrared photography, ARS entomologist Ken Summy easily identifies unplowed or regrowth cotton that should be destroyed to control overwintering boll weevils. (K-2518-8)

Over time, scientists believe, the benefits of stalk destruction will be seen in fewer pesticide applications, less risk of groundwater contamination, and lower costs to growers. The USDA study was used as evidence to support a new Texas law in 1987 requiring that cotton growers destroy stalks annually by Sept. 15 in the Lower Rio Grande Valley and later in more northern parts of the state. Destruction calls for stalk shredding followed by deep plowing, says Summy, of ARS' Subtropical Agricultural Research Laboratory in Weslaco, Texas.

To help state officials enforce stalk destruction, ARS scientists worked out a surveillance system for cottonfields that relies on aerial infrared photos. For about a half-cent per acre, the photos can detect which cottonfields have not been plowed.

"Surveillence has been of great help because the key to making the program work is to quickly find and destroy any remaining cotton," Summy says. "If you wait too long, the plants produce flowerbuds and the boll weevil begins reproducing."

"What this whole thing boils down to is an attempt to control the boll weevil largely through noninsecticidal means," Summy says. "While this program will not totally eliminate the use of insecticides on cotton, there's no question that it will drastically reduce the need for them."—By **Jessica Morrison and Matt Bosisio,** ARS.

Kenneth R. Summy is at the USDA-ARS Subtropical Agricultural Research Laboratory, P.O. Box 267, Weslaco, TX 78596 (512) 565-2423. ◆

An Acre In The Palm of Your Hand


TIM McCABE

Aspirin-sized mature duckweed plants are used in a bioassay to locate traces of allelopathic chemicals. (K-2078-14)

Some plants contain allelopathic compounds, chemicals that serve to repel competing species. These natural herbicides explain why a pole bean may "refuse" to climb a sunflower stalk, or why young tomatoes may be killed off by a nearby walnut tree.

In the best of possible worlds, scientists would be able to take this biochemical trait and tailor it into crops, making them virtually self-weeding. For a long time, though, scientists had no luck harnessing these natural herbicides.

Because the compounds appear only in miniscule traces, the compounds proved impractical to study. No laboratory test was sensitive enough to register their presence; to turn up detectable amounts of the chemicals, it would take acres of experimental plants.

Enter a cadre of Agricultural Research Service scientists in Frederick, Maryland, who realized what was needed—not added acres of full-sized plants, but a more sensitive test using much smaller members of the plant kingdom.

Agricultural Research Service plant physiologist Gerald R. Leather proposed a miniature experimental stand-in for the usual experimental crops, an aspirin-sized aquatic plant called duckweed that lent itself to being grown 24 at a time in wallet-sized plastic plates.

"Each test plate is essentially an acre of field tests in the palm of my hand," Leather points out.

Along with Frank A. Einhellig from the University of South Dakota, he refined a duckweed bioassay or tissue test that allows scientists to detect the herbicidal action of allelopathic chemicals in minute amounts.

Using the test, Leather can trace the impact of a natural herbicide on duckweed tissue in amounts as small as a few parts per billion. "The test is so sensitive, it's like being able to detect the addition of one grain of salt to a jug of water," he says.

Leather tests the fractions of extracts for herbicidal action on duckweed. Then the chemists further break down those fractions found to be effective. Dozens of individual compounds are tested on duckweed in this way. Each compound is dropped into a different "pond" containing a plant.

The team is learning that plants use their self-protecting chemicals in varying combinations and degrees. Further complicating things, the tissues of some plants can contain levels of allelopathic chemicals that would cause injury to the same plants if sprayed onto their surfaces.

Years in the future, the work may lead agricultural researchers to more weed-competitive crop plants with added allelochemicals, via breeding or genetic engineering.

But in biochemistry, news of better experimental methods travels fast. Even in the short time that the duckweed assay has been in use, it's proved to be the most sensitive test of its type. Today it's in use in industrial and academic labs throughout the world, and Gerald Leather is kept busy filling requests from around the world for his duckweed strains.—By **Regina Wiggen,** ARS.

Gerald R. Leather is in USDA-ARS Weed Science Research, Bldg. 1301, Fort Detrick, Frederick, MD 21701 (301) 663-7132. ◆

Nature's Own Herbicides

Oats, walnut trees, some varieties of cherry, and cucumber are among the cultivated plants that make war against their neighbors. Sorghum is another botanical bully; even its own seedlings have difficulty sprouting through last year's sorghum crop residue.

Many weeds also get their competitive edge from allelopathic chemicals. {See *Dyer's Wood Wages Chemical War* , Agricultural Research, *August 1988}*

A theory that's popular among plant scientists postulates that many of our highly bred crop plants have lost an inherent allelopathic ability to fight off neighboring weeds for essential sunlight, soil nutrients, and water.

Some crops such as cucumber and sunflower, the theory continues, are not as far removed from wild relatives, and may have retained their biochemical advantage.

Manure Without Pollution

Animal manure, that most basic of agricultural byproducts, contains nutrients that are good for soil and plants. Recycling it to crops reduces dependence on fossil fuel inputs and contributes to the sustainability of agriculture.

But one of the nutrients in manure—nitrogen—can be a water pollutant. Disposing of this everpresent barnyard bonus presents a tricky problem for farmers.

"When manure is used as a fertilizer, it can be every bit as serious a source of water-contaminating nitrates as commercial fertilizers that are applied to fields," says James L. Butler, an Agricultural Research Service engineer.

"So when we fertilized our 24-acre experimental field with liquid manure, we were concerned it would elevate the drainage water's nitrate level beyond acceptable levels."

Did it? Butler smiles and shakes his head. "The data we have so far shows the nitrate level in our drainage water is very low—well below the Environmental Protection Agency's limit of 10 parts per million for safe drinking water."

"But," he cautions, "we have a large number of water samples and we haven't analyzed all of them yet."

Butler adds: "Before we went to year-round crops, it appeared that we might have a problem of excess nitrates in the ground water."

"Of course, our success hinged on the cropping sequence we worked

ROB FLYNN

Cattle manure is washed from the confinement area with a flush-clean system to underground concrete tanks. After screening, it will be pumped onto fields with irrigation water. (K-3304-6)

out. We haven't used any commercial fertilizer since the project began, yet we have more available nutrients in our soil than when we started," Butler says.

As a bonus for the triple-crop sod system, Butler adds, the year-round ground cover reduces soil erosion to an insignificant amount.

"When an actively growing crop is always in the soil, the crops absorb higher than normal amounts of nitrates whenever the concentration in the soil is excessive."

"When the crops are harvested, the excess nitrates are removed with the crop, and so they're prevented from returning to the soil. This reduces nitrate accumulation, with its potential for leaching to groundwater. So far, cattle have not experienced problems due to excessive nitrates in their forage."

The dairy farm where Butler conducts research is located at the University of Georgia in Tifton. There, cow manure is recycled with a "flush-clean" system. Researchers literally flush water through the confinement area, removing manure to an underground concrete tank.

The now-liquid manure is pumped over a stationary screen where separated solids slide off into a bin. The liquid manure, with only fine particles left, flows into a holding lagoon. The liquid is pumped from the lagoon for irrigation water for the forage crops.

The suspended fine particles are enough to coat corn leaves a dusty brown. "Although we worried that dead organic matter on the leaves would feed plant disease organisms, no problems have turned up yet, and we're in our fifth year of the triple-cropping sequence," Butler says.

The solids that are screened out are spread on nearby fields. Butler, who works on the study with Joseph C. Johnson, Jr., and Larry Newton, both with the University of Georgia's Animal Science department. Newton is testing various composting techniques to destroy disease organisms in these manure solids. If he succeeds,

LOWELL GEORGIA

University of Georgia researchers Joseph Johnson and Diane Marshall analyze for nutritive composition of corn forage grown in the waste management system as compared to commercial fertilizer. (K-3305-3)

the aged manure can be recycled into bedding for the cows, replacing the peanut hulls currently used.

"This entire system seems to be an excellent way to dispose of manure and grow forage crops in areas such as the coastal plain of Georgia. In addition to its cost and environmental savings, it provides a convenient and labor-saving way to both clean up the cattle confinement area and apply fertilizer.

"We are continuing to fine-tune the amount of liquid manure applied, and we're determining the effects of application rates on the nutritive

ROB FLYNN

Above: Despite original concerns that fine particles of manure on the leaves would intensify populations of plant disease organisms, no problems have arisen in five years of study. (K-3303-17)

ROB FLYNN

Left: Standing in sod of Tifton 44, a hybrid bermudagrass, agricultural engineer James Butler examines corn sprayed with liquid manure fertilizer. (K-3302-8)

value of the corn silage, bermudagrass, and rye," he says.

Commercial dairy farms are taking a close look at the University of Georgia dairy farm. One large dairy firm has begun to adopt the system on several of the farms it operates in Georgia. "They've started it with 2 herds of about 1,400 cows each and are planning to use it with 3 or 4 more herds," Butler says.—By **Don Comis,** ARS.

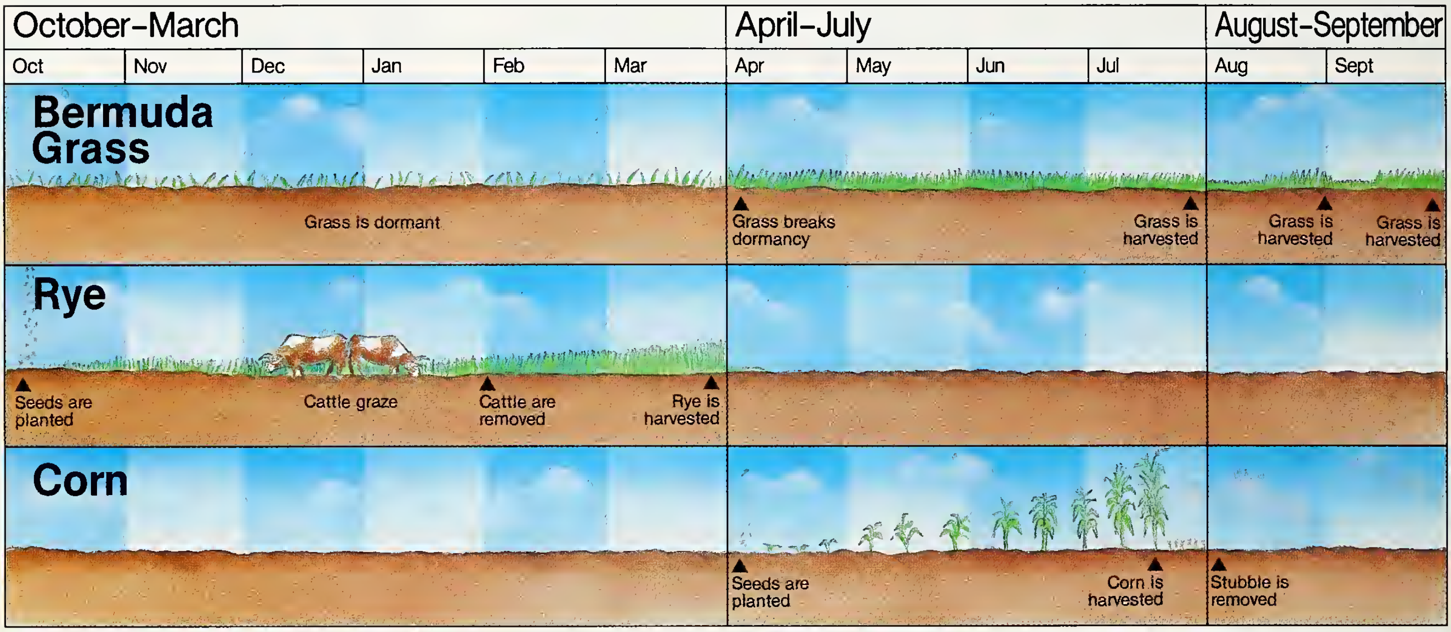
James L. Butler is recently retired from USDA-ARS Crops Systems Research, Tifton GA 31793 (912) 386-3585. ◆

Here's a liquid manure cropping system that builds on a pasture of permanent bermudagrass.

Continuous production of forage is the key to using up nitrates and other nutrients in liquid manure.

When crop roots are active year round, they constantly intercept potential groundwater pollutants.

The system was devised by James Butler and colleagues at the University of Georgia.



October-March

Rye seed is placed by a no-till planter into a slot cut in last year's bermudagrass hay stubble. Throughout the cold season, the perennial bermudagrass lies dormant, while the cold-tolerant rye forage crop soon sprouts and continues to grow.

Cattle continuously graze the rye from November until about mid-February, when they are moved to other pastures. The rye is allowed to grow tall enough to start forming seeds, a measure to prevent regrowth from the roots when later crops are planted. Then the rye crop is harvested as silage.

April-July

Immediately after the harvest of rye silage in mid-to-late March, a special machine, called a ripper-planter, **seeds corn and breaks up the soil,** which has so recently been compacted by cattle hooves.

Benefiting from a generous application of **wastewater containing manure nutrients,** the well-nourished corn grows rapidly. In late July, it is harvested for silage.

August-September

Accumulated **bermudagrass and corn stubble** are harvested right away. This low-quality hay may be used to maintain dry cows or winter beef cattle.

No longer overshadowed by corn plants, the bermudagrass provides an abundant **second and third crop of hay** throughout the late summer.

Helping Small Farmers Make Big Decisions

Am I raising the right livestock—or growing the right crops? Should I expand my acreage for one crop and cut down on another? How much profit could I make with a different system?

These are critical questions for more and more small farmers struggling to make ends meet.

And they're questions that a new computer program—called APEX—can help answer.

Expert systems such as APEX are computerized teachers programmed to communicate the knowledge of experts in specific fields through question-and-answer dialogs with their users.

APEX—for Agricultural Planning Expert—allows small farmers to tap the expertise of agricultural scientists, economists, and extension agents alike.

Jointly developed by the Agricultural Research Service and the University of Maryland, the program is now being tested by the Maryland Cooperative Extension Service in St. Mary's County on the Chesapeake Bay.

"We run APEX for the farmers," explains Maryland cooperative extension agent Daniel J. Donnelly, "as opposed to farmers running it on their own computers. The program was designed to help us help them. They come into our office and sit down with us, and we go through it together."

The expert system enables extension agents to quickly and conveniently show individual farmers how well they might do raising one or more commodities from a broad array of possibilities.

"With APEX, we can get farmers to at least consider diversifying or shifting from one crop to another."

Daniel J. Donnelly, Cooperative Extension Service

The farmer's personal preferences are taken into account, along with his or her available acreage, time and labor capabilities, and requirements in the way of profits.

"With APEX, we can get farmers to at least consider diversifying or shifting from one crop to another," says Donnelly, who worked with ARS research economist Yao-Chi Lu and Maryland farm management specialist Richard A. Levins (now at the University of Minnesota) to create the expert system.

The Congressional Office of Technology Assessment, in a study co-authored by Lu, reports that most farms having less than $100,000 in annual sales are not economically viable.

These farms do not bring significant income to their operators, according to Lu. They survive, he says, for reasons that often have little to do with traditional farm financing methods or management.

Their operators might have substantial off-farm income, for example, and are able to run the farm part time—almost like a hobby. Or perhaps they have no other employment possibilities and are willing to accept a low return for their time and labor.

"Either way," says Lu, "the purpose of APEX is to enhance the profitability of these enterprises."—By **Steve Miller**, ARS.

Yao-Chi Lu is at the USDA-ARS Systems Research Laboratory, BARC-West, Beltsville, MD 20705 (301) 344-1821.

So Who's Computing?

Without help from the Extension Service, few small farmers would be equipped to run programs such as APEX on their own. According to USDA's Economic Research Service *[Farmline, Vol. X, No. 10]* less than 3 percent of all farms use computers and these are concentrated in the more sizeable operations. The report notes that nearly 15 percent of the operators of "large" farms (annual commodity sales of at least $250,000) used computers in 1987.

National Agricultural Statistics Service's Diane Willimack says that a substantial number of farm computer users "appeared to have written their own accounting programs," suggesting "that available software programs may not always fit a farm operator's particular needs."◆

Tools for Sustaining the Soil

DOUG WILSON

Left: Engineers John Dreissen (left) and Keith Saxton inspect the underside of their cross-slot grain drill. Visible on the staggered two-row system are the serrated coulters that cut the soil, enabling fertilizer and seed to be placed below the soil surface. (K-2814-14)

Right: Angled wings on both sides of each of the drill's eight coulters close the slot and pack the soil. Each coulter and wheel unit is individually suspended. (K-2815-14)

To help the land hold onto the soil and the soil to hold onto the rain, Agricultural Research Service scientists have been developing, testing, and tinkering with the machinery that farmers use.

The goal is to have machines that let a farmer plant without disturbing the surface of the land or compacting the subsurface in order to limit soil erosion and evaporation of scarce water resources.

Modifications of machinery in use, like the Paraplow and the sweep plow, and newly designed implements, like the slot mulcher and cross-slot drill, not only help prevent soil from eroding, they can make a soil more productive—richer in beneficial microbes and earthworms and a better environment for seed germination.

At the Land Management and Water Conservation Research Laboratory in Pullman, Washington, soil scientist Robert I. Papendick has been testing the Paraplow, a conservation tillage implement developed in Great Britain.

Conservation tillage reduces cultivation and leaves residues of a previous crop as a surface cover—which lessens soil erosion and evaporation. In the Pacific Northwest, conservation tillage can reduce soil loss from 20 tons an acre—under conventional tillage—to less than 2 tons, according to Papendick.

The Paraplow, actually a series of staggered chisels mounted on a frame, eliminates compaction, Papendick says.

Conventional tillage can cause compaction of wet clayey soils that makes it harder for roots to penetrate deep and closes off the pores that aerate the soil.

Each chisel has a leg that goes straight down and then bends to the side at a 45° angle. When the chisels are pulled through the soil, soil flows over each bent wing, as air flows over an airplane's wings.

The Paraplow lifts and cracks the soil, but only slightly disturbs the soil surface. The wing design limits compaction, and by staggering the chisels just so, even smearing by one chisel is undone by the next chisel in line on the frame.

Keith E. Saxton, an agricultural engineer at Pullman, says "The Paraplow represents a major advance in soil tillage equipment. It restores productivity in compacted, eroded soils by breaking up dense soil layers, improving the root zone and the water intake."

ARS microbiologist Lloyd F. Elliot modified the commercially built Paraplow to dispense phosphorus fertilizer at depths of 14 to 18 inches as it cultivates.

"Deep fertilizer placement," says Elliot, "should encourage rooting at greater depths and help restore soil productivity in marginal soils." In another project, Keith Saxton is also working on a new cross-slot drill opener to plant the seeds of wheat and other cereal grains in residue-covered soil untilled or minimally tilled.

The cross-slot drill cuts thin slits through crop residues into the land and deposits seed and fertilizer, all in one pass.

Unlike present no-till planters used in the conservation tillage system, which bury 30 to 50 percent of crop residues, Saxton's cross-slot drill planter buries no more than 10 percent of residues.

Because the drill disturbs so little soil and crop residue, more water is trapped in the seed zone. This minimizes evaporation and promotes seed germination. Seed and fertilizer are deposited more accurately through

DOUG WILSON

the residues than is possible with no-till machines currently available, according to Saxton.

The drill is also smaller and weighs less than other available no-till drills. It could wind up costing farmers one-half to two-thirds of what it does now to own and operate the larger, heavier drills currently in use, Saxton says. And a 1988 summary of more than 250 comparison plots of winter wheat reflected a 15-percent yield advantage of the cross-slot over a double-disk drill.

A Seattle-based company, Agrisystems International, plans to have a commercial version of the cross-slot drill on the market in limited quantities by spring.

"The cross-slot drill is designed with the idea of making the needs of the seed for a particular environment the most important consideration," says Stephen Plowman, Agrisystems International CEO. "The cross-slot drill creates the most amenable type of slot opening to grow seeds in. It creates a furrow like a zipper—opening the soil and then closing the opening over the seed, maintaining the humidity and other natural conditions."

Another new tillage tool, one being patented by soil scientist Lloyd N. Mielke and his colleagues in Lincoln, Nebraska, adds enhancing soil microbial activity to conservation tillage. Mielke's invention is a modification of the sweep plow.

Since the great drought of the 1930's, the sweep plow has been a mainstay of the Great Plains wheat growers for subsurface tillage of fallow or bare fields. A sweep is a flat V-shaped blade with a "wingspan" of up to 5-1/2 feet. In operation, the blade is pulled horizontally through the soil, point first, about 3-4 inches below the surface.

But as the sweep plow undercuts emerging weeds and loosens the soil above the blade, the bottom edge "shears off the soil," Mielke says. "The sheared soil plane looks as though someone smeared it with a giant putty knife, closing up root and worm holes and similar cracks and openings."

The shear plane curbs the infiltration of water, deprives microbes of oxygen, forces roots to grow sideways and may cut crop yields, and it eventually forms a virtually impenetrable barrier.

In Mielke's design, four 6-inch-long shanks are attached to the underside of the sweep blade—two to a side. The shanks incline toward the center so that as they travel forward, their geometry of bends thoroughly breaks up the soil to a depth of 8-10 inches below the surface, leaving the soil porous and well aerated.

Water is trapped in the pores—subterranean troughlike reservoirs that the shanks create just below the tilled zone. Porous soil helps foster microbial activity that unlocks extra nutrients for crops.

But soil pores must hold the proper balance of water and air for microbes to make nutrients available to plants. Tests indicate the soil porosity created by the shanks in the lower part of the sweep-tilled zone creates a water:air ratio that is ideal.

"Over time, using a plow like this, we should see an improvement in the organic quality of the soil at the surface layer that should lead to a soil more like what exists in nature," Mielke says.

On the downside, modified sweeps like Mielke's do require more than twice as much tractor drawbar power as the sweep blade without shanks. But it is possible to scale down modified sweeps for small farm use, he expects.

Mulching can also help prevent soil erosion and increase water storage, and Saxton has turned his farm machinery research in that direction, too.

Paraplow under test on the highly-erodable volcanic soil of the Palouse in eastern Washington State. (K-2025-12)

He has designed a slot mulcher, a machine that cuts slots—small trenches about 3 inches wide and 10 inches deep—into the ground about 12 to 20 feet apart along the contour lines of the land and stuffs them with wheat and barley straw left in the fields after the harvest.

Melting snow and rain cross the trenches at right angles, and the straw sticking up slows the water so that soil particles settle out.

Eventually, the mulch decomposes, and that provides organic material to the soil as well.

In tests, slot mulching cut annual erosion from cropland to 1 ton or less per acre. "This is a dramatic improvement for Washington's Palouse Hills region where soil losses often run 20 to 30 tons per acre with conventional tillage," Saxton says.

Saxton expects fields would need only one slot mulching treatment a year, timed for right after the harvest. The slots remain effective until the tops of the slots are buried by sediment or farm machinery.

"It's an excellent way to infiltrate water into a field," Saxton says. "We hope that a farm machinery company will be interested in picking up the idea."—By **J. Kim Kaplan,** ARS.

Keith A. Saxton and Robert I. Papendick are in USDA-ARS Land Management and Water Conservation Research, Smith Agricultural Engineering Bldg., Washington State University, Pullman, Washington 99164 (509) 335-2724.

Lloyd F. Elliot, who worked on the Paraplow at Pullman, is now at ARS' U.S. Cotton Research Station, 17053 Shafter Ave., Shafter, CA 93263 (805) 746-6391.

Lloyd N. Mielke is in USDA-ARS Soil and Water Conservation Research, East Campus, University of Nebraska, Lincoln, NE 68583 (402) 472-1516. ◆

Sustainable Agriculture Through The Years

The following selection of articles from *Agricultural Research* emphasizes the agency's long-term commitment to conserving soil and water resources, finding biological controls for pests, and lowering other farm inputs while maintaining the economic health of the nation's food and fiber producers. To request reprints, please contact the Editor, *Agricultural Research,* Bldg. 005, BARC-West, Beltsville, MD 20705. (301) 344-3280

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Scientists Fight Brush With Imported Insects	**April 1989**
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Kenaf Paper: A Forest-Saving Alternative	**October 1988**
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When Plant Cooling Fails...

Scientists have known for about 50 years that plants use most of the water they absorb to cool themselves off by transpiration—releasing water vapor through leaf openings called stomates.

As Jerry E. Quisenberry, director of the Agricultural Research Service Cropping Systems Research Laboratory at Lubbock, Texas, notes, "In the morning, plant leaves are at air temperature. But as the day warms up, the plant warms up too, until it reaches its optimal temperature range.

"If water becomes scarce, the cooling process begins to shut down—the stomates begin closing and the plant's temperature rises. And should air temperature rise above 100°F, as it does here in the summer, the plant's enzymes become less effective. "Eventually, unless it can get both the water and the cooler temperature it needs to maintain itself, the plant dies."

Scientists think they may know what is going on inside the plant's cells and just why the heat does damage. They hope the discovery leads to crops better able to withstand not just heat and drought but other stresses as well.

"Two enzymes found in all plants are now thought to function best within a temperature range we call a thermal kinetic window," says plant physiologist Jerry L. Hatfield. (Hatfield is now laboratory director at ARS' National Soil Tilth Laboratory in Ames, Iowa.)

"When the plant's temperature rises above the window, it begins losing its ability to cope with heat stress. This finding," he says, "may be an important step toward breeding and possibly genetically engineering crop plants that can tolerate stresses better."

In living cells, thousands of enzymes act as catalysts for essential life processes such as making and breaking down proteins.

Hatfield says that thermal kinetic windows vary by plant species and "are much narrower than we expected. Corn, for example, has a range of 77°F-88°F. For cucumbers, it's 93 to 100."

Hatfield's colleagues at Lubbock, plant physiologists John J. Burke and James R. Mahan, were the first to analyze the two enzymes' activity at different temperatures.

The enzymes are from corn, wheat, cotton, spinach, and cucumbers.

JACK DYKINGA

Plant physiologist Jerry Hatfield uses an infrared thermometer to determine leaf temperature on heat and water stressed cotton plants. Studies are aimed at helping plants tolerate heat and drought. (K-2981-16)

Mahan says, "We're in our second year of field tests for cotton and wheat, and we're planning lab studies with a half-dozen other enzymes."

Mahan says that one of the two enzymes studied, glutathione reductase, stops the buildup of potentially lethal waste byproducts as a plant copes with heat stress. The other, hydroxypyruvate reductase, is thought to protect photosynthesis in times of drought or other stresses.

Quisenberry says other studies will attempt to transfer one plant's genes for controlling an enzyme's temperature-specific behavior into other plants. "If we give plants new genes enabling them to grow better at a warmer—or cooler—temperature, that would really help farmers. The enzyme studies may also give us a new way to screen plants for their ability to cope with heat, drought, and other stresses.

"These advances are a long way off," he cautions, "but they could lead to crops better equipped to face climatic changes such as the gradual heating that may occur from the buildup of carbon dioxide in the Earth's atmosphere."—By **Don Comis,** ARS.

Jerry E. Quisenberry is at the USDA-ARS Cropping Systems Research Laboratory, Route 3, Box 215, Lubbock, Texas 79401. (806) 746-5353. James R. Mahan and John J. Burke are in USDA-ARS Plant Stress and Water Conservation Research, at the same address and phone number. ◆

The Best Bacteria for Soybean Roots

Bacteria compete fiercely for a home on soybean roots, and serogroup 123 strains of *Bradyrhizobium japonicum* usually win the race at the expense of other bacteria such as strain USDA 110.

This is unfortunate for farmers because strain 110 delivers more nitrogen to developing pods.

More than 60 percent of the $11 billion U.S. soybean crop relies on commonly occurring bacterial strains, classified as serogroup 123, to capture nitrogen from the air and fix it in the roots as free fertilizer.

ARS scientists hope to change all that. They discovered soybean breeding lines that reject serogroup 123 strains, and found three soybean genes that seem to be responsible for this rejection. They have also found genetic material in USDA 110 that influences one of the new soybean lines to favor it.

The scientists have applied for a patent outlining a two-step approach that could boost farm income.

Step one: Combine the three soybean genes into one soybean line that will reject inefficient bacterial strains of *B. japonicum.*

Step two: Bioengineer a "super bacterium" possessing genes that are attractive to the new soybean.

Farmers would buy the bacterium in granules or other form, as they have for many years for nonengineered bacteria, and mix the granules with the new seeds. The bacterium/seed package would ensure higher yields. Extimates suggest increases of 7 percent or more.

And the approach should work with beans, peas, and other crops planted by gardeners as well as farmers.—By **Don Comis,** ARS.

Technical information is available from Perry B. Cregan, and Harold H. Keyser, USDA-ARS Nitrogen Fixation and Soybean Genetics Laboratory, Beltsville, MD 20705 (301) 344-1723. U.S. Patent Application Serial Number 07/087,356, "Novel Approaches Useful for the Control of Root Nodulation of Leguminous Plants." ◆

DESH PAL VERMA

Legume roots heavily nodulated with nitrogen-fixing bacteria. (K-3337)

Probing Plant Preferences

Leon Kochian isn't asking for much. He merely wants to know the most intimate secrets of plant cells. Specifically, he's interested in plant cells' "tastes"—why and how they take up more of certain nutrients than others.

This isn't just idle curiosity. If, for example, he can gain new knowledge about why, how, when, and where nitrate or ammonia are absorbed by the plant's cells, researchers might develop a way to step up those actions so farmers could get a lot more bang for their nitrogen fertilizer bucks.

Kochian, a plant physiologist with the Agricultural Research Service, has gone to extraordinary lengths for these sorts of answers—20 millionths of an inch, to be exact. That's the diameter of the microelectrode probe he and research support specialist Jon E. Shaff are using on individual plant cells at the U.S. Plant, Soil, and Nutrition Research Laboratory at Ithaca, New York.

"Each cell is enclosed by a natural membrane like a plastic wrap," Kochian explains. "Imbedded in this wrap are proteins that let certain things in or out of the cell—things like potassium, hydrogen, iron, or calcium. These are all electrically charged ions.

"We push the tip of the probe through the outer membrane of the cell, and the membrane closes around it. Then we can study the voltage across the membrane to see when, say, a potassium ion moves in or out of the cell."

"We placed a seedling in a special chamber containing a solution of a known potassium concentration," he says. "With microelectrodes, we can follow what's happening to individual root cells as they absorb potassium."

The information garnered with the microelectrodes could someday help crops thrive in spots where they currently can't grow well.

"For example," Kochian says, "aluminum toxicity is a real problem in certain areas of the United States. It appears to affect the cell membrane. We're using microelectrodes to study the reasons some plants are so sensitive and others aren't.

"We don't have the answers yet, and it's going to take a while. But I think we're poised at the point where we will really start learning the "how" of nutrient transport in plants."—By **Sandy Miller Hays**, ARS.

Leon V. Kochian is at the U.S. Plant, Soil, and Nutrition Research Laboratory, Tower Road, Ithaca, NY 14853 (607) 255-2454. ◆

Predicting Insecticide Resistance

Insects' ability to become resistant to pesticides has always been a threat to the best laid plans for their control. Yet resistance isn't usually recognized until a pesticide begins to fail.

ARS ecologist Jane L. Hayes and postdoctoral associate Michael Firko are working on a way to predict the chance that resistance to pesticides could occur in a particular population of insects.

"Most of the time, when scientists test for resistance, the best they get is a snapshot of what resistance is already present," Hayes says. "What we want

is a measure of prediction—that is, how likely is resistance to develop. This will tell pesticide users how careful they need to be."

Increase in the incidence of resistance in an insect population can be slowed by better pesticide management within the label requirements, e.g., alterations in intervals, patterns, and quantities applied.

Population genetics provides a count of resistant vs. susceptible individuals in the population at the time of sampling, with tested insects categorized simply as dead or alive.

What Hayes and Firko measure instead is how widely a population varies for pesticide resistance. The wider the variation, the more possibility there is for the entire population to evolve the characteristic.

"We apply the pesticide to a sample of the insect population and then measure how affected they are," Hayes says. "Unlike population genetics studies that may count a groggy insect as dead, we use a scale of 0 to 10—10 being the insect sneers at the pesticide and 0 that it just about dies at the sight of the label." They score each insect many times over 3 days to arrive at an average score.

Besides providing information that prediction of pesticide resistance can be based on, Hayes says, these methods may supply a means of identifying insect populations, allowing scientists to track migrations and intrusions of one population into another's territory, since the degree of genetic variability in geographically distinct populations is potentially unique.

In their first major study, Hayes and Firko applied sibling analysis population genetics to the tobacco budworm. The tobacco budworm is one of the major pests of cotton, as well as being a frequent problem in tomatoes, peanuts, soybeans, and other crops.

"Some pesticide resistance has already been seen, so we weren't surprised to find a high degree of genetic variation in the population we sampled," Hayes says.

Already growers must take a more careful approach to pesticide use to avoid increasing resistance in the budworm.—By **J. Kim Kaplan**, ARS.

Jane L. Hayes and Michael Firko are in USDA-ARS Biology, Ecology, and Biocontrol of Insect Research, Jamie Whitten Delta States Research Center, P.O. Box 346, Stoneville, MS 38776 (601) 686-2311. ◆

Nikkomycin—Antibiotic for Plants

Scientists are working to transfer to plants genes from a soil bacterium that could one day provide them with a built-in defense against fungi.

The bacterium, *Streptomyces tendae*, contains genes that direct the production of nikkomycin, a natural antibiotic already proven deadly to fungi such as *Cladosporium*, *Aspergillus*, and *Colletotrichum*. Nikkomycin produced either inside or outside a plant could serve as a natural food preservative by prohibiting fungal growth. Nikkomycin has been proven nontoxic in tests with laboratory mice.

"This is what we call a self-protectant," says Paul Engel, a geneticist with the Agricultural Research Service. "These genes [from *S. tendae]* are like a manual that tells you how to put together simple elements, like nitrogen, carbon dioxide, and oxygen, to make nikkomycin. The genes could be incorporated into seeds or other bacteria."

S. tendae is currently the only known source of nikkomycin, Engel says. So far, it hasn't been used commercially against fungi like those that produce aflatoxin, because it's too expensive. Also, nikkomycin has been applied to plants in a spray, but because it is water soluble, it easily washes off in rain or a heavy dew.

In January, Engel and his colleagues at the Microbial/Plant Technology Research unit in New Orleans successfully transferred a cluster of nikkomycin-producing genes from *S. tendae* into *S. lividans*, a member of the same family that doesn't make nikkomycin.

Engel took DNA from *S. tendae* and patched it onto another piece of DNA found in *S. lividans*. Once the genes were transferred, nikkomycin production began in *S. lividans*.

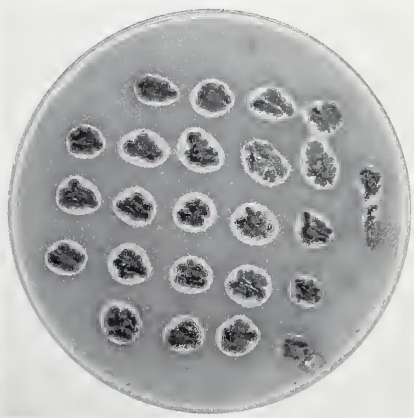
Using the same principle, transfer of the genes into plants could occur within the next 5 years, he says. As the altered plants grow and produce seeds, those seeds would contain the genetic trait that directs nikkomycin production.

Or scientists may decide to build natural factories that make nikkomycin by transferring genes to bacteria that attach to various plants above and below ground.

This genetic transfer might protect the plant from fungal invasion. And as bacteria multiply, this trait would be passed to future generations.

Engel notes that Christiane Bormann, of the University of Tübingen, West Germany, is doing similar research on nikkomycin. Bayer AG. of West Germany holds a 1977 patent for the agricultural use of nikkomycin.—By **Bruce Kinzel**, ARS.

Paul Engel is in USDA-ARS Microbial/Plant Technology Research, Southern Regional Research Center, P.O. Box 19687, New Orleans, LA 70179 (504) 286-4200. ◆



BRIAN ESCHETTE

Genetically-engineered *Streptomyces* colonies produce an antifungal substance that kills (clear areas around colonies) fungus in this laboratory dish. (89BW1639)

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